POLAR NOISE SHAPING

FIELD

[0001] The subject matter described herein relates to wireless communications.

BACKGROUND

[0002] When a signal is converted from a floating point to a fixed point signal, the conversion may be performed before a digital-to-analog converter. The difference between the floating point input signal and the fixed point output signal represents an error and, in particular, quantization error, which may also be referred to as quantization noise. In radio transmitters, this quantization noise is conventionally attenuated right after the digital-to-analog converter by analog filters before the signal is up-converted into radio frequency. Rather than use analog filters, some transmitter technologies may transmit fixed point radio frequency signals including quantization noise.

SUMMARY

[0003] Methods and apparatus, including computer program products, are provided for polar noise shaping.

[0004] In one aspect there is provided a method. The method may include receiving a first error signal representative of a first noise including a first quantization noise carried by a quadrature signal; receiving a second error signal representative of a second noise including a second quantization noise carried by an in-phase signal; and determining one or more bits in a polar domain, wherein the one or more bits cancel a portion of the first noise and the second noise represented by the first error signal and the second error signal.

[0005] In some variations, one or more of the features disclosed herein including the following features can optionally be included in any feasible combination. The method may further include combining, in the polar domain, the one or more bits with the amplitude signal and the phase signal to cancel the portion. The combining may include subtracting. Two sigma delta modulators may determine from the first error signal and the second error sigma, the one or more bits. The two sigma delta modulators may include two parallel sigma delta modulators, wherein the two parallel sigma delta modulators each have a feedback gain adaptively chosen according to at least the amplitude signal, the phase signal, and one or more signs of the two parallel sigma delta modulators outputs. The feedback gain may be chosen so that it is proportional to a rectangular domain change equivalent of least significant bit changes of the amplitude signal and the phase signal. One of the gain levels may be chosen from the one or more gain levels, so that it provides a high gain in the two parallel sigma delta modulators. The two sigma delta modulators may have different non-even quantizer levels. The non-even quantizer levels may be adaptively chosen according to at least the amplitude signal, the phase signal, and the one or more signs of the two parallel sigma delta modulators outputs. The non-even quantizer levels may be chosen, such that the non-even quantizer levels may be proportional to rectangular domain change equivalents of one or more least significant bits changes of the amplitude signal and the phase signal. The first and second noise may be due in part to at least one of a regular or an irregular step size of quantized polar domain signals.

[0006] The above-noted aspects and features may be implemented in systems, apparatus, methods, and/or articles depending on the desired configuration. The details of one or more variations of the subject matter described herein are set forth in the accompanying drawings and the description below. Features and advantages of the subject matter described herein will be apparent from the description and drawings, and from the claims.

DESCRIPTION OF THE DRAWINGS

[0007] In the drawings,

[0008] FIG. **1** depicts an example of a polar noise shaper, in accordance with some example embodiments;

[0009] FIG. **2** depicts an example of a simulated plot of the cancelation of quantization noise provided by the polar noise shaper, in accordance with some example embodiments;

[0010] FIG. **3** depicts another example of a polar noise shaper, in accordance with some example embodiments;

[0011] FIG. **4** depicts an example of a two-dimensional sigma delta modulator, in accordance with some example embodiments;

[0012] FIG. **5**A depicts an example of rectangular domain to polar domain mapping, in accordance with some example embodiments;

[0013] FIG. **5**B depicts an example process for determining a least significant bits which can be used to cancel noise including quantization noise and the like, in accordance with some example embodiments;

[0014] FIG. **6** depicts another example of a polar noise shaper, in accordance with some example embodiments;

[0015] FIG. **7** depicts another example of a two-dimensional sigma delta modulator, in accordance with some example embodiments;

[0016] FIG. **8** depicts an example process for polar noise shaping, in accordance with some example embodiments;

[0017] FIG. **9** depicts an example of a user equipment, in accordance with some example embodiments; and

[0018] FIG. **10** depicts an example of a network node, in accordance with some example embodiments.

[0019] Like labels are used to refer to same or similar items in the drawings.

DETAILED DESCRIPTION

[0020] FIG. **1** depicts an example of a radio frequency transmitter **100** including a modem **110** (for example, a Cartesian floating point modem and the like), a radio frequency (RF) power digital-to-analog converter (DAC) **199**, and an RF polar shaper **150**. The RF power DAC may perform a direct conversion of signal **112**A-B as in-phase (I) and quadrature phase (Q) signals into radio frequency signal. The input **112**A may represent a high bit count quantized version or floating point version of the in-phase signal, while input **112**B may represent a high bit count quantized version or floating point version of the quadrature phase signal. A rectangular-to-polar quantizer (RTPQ) **116** may then convert rectangular signals **112**A-B to lower bit count polar form before modulation and transmission via antenna **180**.

[0021] The RF power DAC (digital-to-analog converter) may be used to transmit RF signals with the capability to choose bandwidth, carrier frequency, and/or multiple carriers flexibly, on the fly in a power efficient transmitter. However, RF power DACs may not have a conventional baseband, which can include for example baseband filtering and the like.